Te Ahu a Turanga; Manawatū Tararua Highway

Notices of Requirement for Designations Volume Two: Assessment of Effects on the Environment and supporting material

NZ TRANSPORT AGENCY
WAKA KOTAHI

New Zealand Government

PART J:
APPENDICES

APPENDIX FOUR:
BRIDGE & RETAINING WALL DESIGN PHILOSOPHY REPORT

Te Ahu A Turanga;
Manawatū Tararua Highway Project

Manawatū Gorge Replacement Route

Bridge and Retaining Wall Design Philosophy Report

Report

Holmes Consulting

Revision 3
26 October 2018
137135.00

Report

Te Ahu A Turanga; Manawatū Tararua Highway Project
Bridge and Retaining Wall Design Philosophy Report

Prepared For:
New Zealand Transport Agency

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Prepared By:

Rob Presland
TECHNICAL DIRECTOR
Holmes Consulting LP

Reviewed By:

Phil Gaby
PROJECT DIRECTOR
Holmes Consulting LP

Holmes

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Holmes

EXECUTIVE SUMMARY

General

The existing State Highway 3 through the Manawatū Gorge has been permanently closed, for safety reasons, following a series of large landslides affecting the road and retaining walls within the Gorge. This Project is to provide a new resilient, safe and efficient connection between the eastern and western sides of the Ruahine and Tararua ranges.

This report outlines governing design principles to be considered in the development of bridge structure and retaining wall options along the route. Based on the indicative geometric layout design for the Project, where bridge structures are known to be required, potential options for bridge structural forms are proposed.

This report should also be read in conjunction with the Project Environmental and Cultural Design Framework (ECDF) document which sets out the environmental and cultural context, and identifies design principles and outcomes sought in the design of the Project. The document outlines key environmental and cultural aspects that need to be considered during detailed design and construction of the Project. It describes the environmental and cultural context, introduces design principles and outcomes and identifies opportunities for NZTA and partners, in particular iwi, that can be considered alongside the construction of this Project and may require input from other parties.

Bridges & Retaining Walls

The indicative geometric route design includes a number of bridges providing property access, river and stream crossings. The most significant bridge structure is a new bridge required to span the Manawatū River at the entrance to the Gorge. It is possible that further bridge structures may be required, as a result of detailed design development.

Major retaining walls and reinforced soil slopes may feature along the route. Potential options for retaining wall/slope types are discussed.

Summary of Guiding Principles for Design of Bridges & Retaining Walls

The key 'Guiding Principles' for development of the bridge and retaining wall solutions for the Project are listed below:

- Bridge and retaining wall solutions are to be developed in conformance with the New Zealand Transport Agency Bridge Manual (NZTABM) (NZTA, 2013).
- Best value bridge solutions, with due consideration for whole of life performance, are recommended ahead of cheapest conforming design options.
- Appropriate aesthetics are important, and due consideration must therefore be given to this in the development of the structural concepts.
- Development of bridge structure (and retaining wall) solutions and aesthetics should be considered in line with the principles outlined in the ECDF.
- Where possible, integral abutments and piers should be considered for the bridges to eliminate maintenance associated with bearings and joints, in addition to providing additional structural redundancy and robustness.
- 'Low damage' seismic design approaches are considered desirable for the larger bridge structures in particular, given the high seismicity of the region.

Bridge Types

The guiding principles above have led to the following indicative / preliminary bridge options being proposed for the Project:

- Spans up to 6m – Reinforced concrete box structures.
- Spans up to 25m – Generally hollow core prestressed concrete decks.
- Spans ranging from 25m to 35m – Super 'T' prestressed concrete girder decks.
- Spans ranging from 35m to 60m – Steel 'I' girders or steel box girders with composite reinforced concrete deck slabs. Concrete box girders are also feasible.
- Spans > 60m (Manawatū River Bridge) – Steel box girder beam arrangement (continuous span arrangements up to 60m) or balanced cantilever construction, steel truss, steel box girder or concrete box girder (continuous span arrangements >60m).

Alternative bridge structure options are possible, to be considered and developed further through the design phases for this Project.

Retaining Walls

The guiding principles above have led to the following indicative / preliminary retaining options being proposed for the Project:

- Mechanically stabilised earth (MSE) walls are proposed for vertical retaining walls. Options for concrete panel or block facing to the walls are available.
- Reinforced soil slopes are considered feasible for embankments detailed with 45° or steeper slopes.

Alternative retaining options are possible, to be considered and developed further through the design phases for the Project.

1 BACKGROUND

1.1 Introduction

The section of State Highway 3 (SH3) traversing through the Manawatū Gorge provides a key link between communities within the Manawatū Region and inter-regional travellers as one of the few connections between the western and eastern sides of the Tararua and Ruahine Ranges.

This section of road has been permanently closed since July 2017, for safety reasons, following a series of large landslides affecting the road and retaining walls within the Gorge. The two existing alternative routes, Saddle Road and Pahiatua Track, were not designed to cater for the increase in traffic flows over long periods, especially high volumes of heavy vehicles, that has resulted from closure of SH3.

The detour via Saddle Road means all traffic using this route must pass through Ashhurst town centre causing significant community concern in terms of noise, safety and amenity. The detour is an average of approximately 9 minutes longer to travel for general traffic and 15 minutes for freight vehicles. It is also causing significant constraints on the freight industry, commuters and inter-regional traffic, with significant economic impact due to increased vehicle operating costs, travel time and other economic dis-benefits such as impacts to local businesses.

There is a clear and urgent need to develop and construct an alternative route which can achieve the following Project objectives:

- To reconnect the currently closed Manawatū Gorge SH3 with a more resilient connection.
- To reconnect the currently closed Manawatū Gorge SH3 connection with a safer connection than the Saddle Road and Pahiatua Track.
- To reconnect the currently closed Manawatū Gorge SH3 with a more efficient connection than the Saddle Road and Pahiatua Track.

1.2 Indicative Main Alignment

The proposed alignment passes to the north of the Manawatū Gorge, south of Saddle Road, through the Te Āpiti wind farm. The alignment utilises the natural features of the Ruahine Ranges and the relatively flat crest along the top through the wind farm.

The western end commences at the existing Ashhurst SH3 bridge, progressing north over the Manawatū River and railway immediately west of the Gorge on a new bridge structure before climbing the hill through a combination of cuts and fills until reaching the hill plateau. Maximum grades in the order of 8% are expected.

This route crosses the Ruahine Ranges through the Te Āpiti wind farm on a relatively flat grade before turning southeast to link with SH3 through Woodville. The proposed route will affect some existing wind turbine locations, which may need to be removed or relocated.

The overall route is in the order of 11.5km long, comparable to the existing Gorge route length. Extensive cuts and fills are expected, particularly on the slopes up to and down from the flat crest through the windfarm. Maximum cut depths of up to 45 metres and fill heights up to 30 metres are anticipated.

The main alignment will involve land in three districts: Palmerston North City, Manawatū District and Tararua District, as well as Horizons Regional Council.

The key design features of the main alignment are:

- Two lane rural highway, with crawler lanes each way for a majority of the alignment;
- Maximum gradient of 8%;

- Design speed of 100 km/h; and
- Continuous wire rope median barrier separation and wire rope barriers to verges.

1.3 Purpose and Scope of this Report

The purpose of this report is:

- To outline the governing design principles to be considered in the development of the bridges and retaining walls found along the main alignment.
- To outline potential bridge forms for sites where bridges are required throughout the route.

This report should be read in conjunction with the NZTA Bridge Manual, which sets out the criteria for the design and evaluation of bridge structures and the design of earthworks and retaining structures.

This report should also be read in conjunction with the Project Environmental and Cultural Design Framework (ECDF) document which sets out the environmental and cultural context, identifies design principles and outcomes sought in the design of the Project. The document outlines key environmental and cultural aspects that need to be considered during detailed design and construction of the Project. It describes the environmental, cultural context, introduces design principles and outcomes and identifies opportunities for NZTA and partners, in particular iwi, that can be considered alongside the construction of the Project and may require input from other parties.

1.4 Development of the Current Design

Following the closure of the Manawatū Gorge in April 2017, a Detailed Business Case has been developed, including an options assessment process to identify a long-term replacement route. Route options were refined from an initial long list of 18 options to a short list of four options.

The preferred route, Option 3 from the short list, was identified in March 2018. This route has been developed through the current phase of work in order to inform the required designation, land purchase requirements and understand the effects of the Project for the purposes of resource consenting.

1.5 Project Description

1.5.1 Indicative Main Alignment and Designation Corridor

The Project is 11.5km of new State highway running from the State Highway 3 western entry to the closed Manawatū Gorge route, across the Ruahine Ranges north of the Manawatū Gorge and south of Saddle Road, emerging near Woodville. The Manawatū Gorge route accommodated 7,620 vehicles per day, including 11.3% heavy vehicles in 2016, prior to being closed. The Project is expected to accommodate approximately 9,700 vehicles per day from its anticipated opening date in 2025. The Project includes:

- two lanes (one in each direction with additional crawler lanes where the highway grades require and where extension of the crawler lane provides a consistent corridor);
- new bridge structures (crossing Manawatū River and unnamed streams and property access underpasses);
- pipe or box culverts for cross drainage;
- new roundabout connections at State Highway 57 and existing State Highway 3; and
- the reconfiguration of a portion of the Te Āpiti wind farm.

The sectors of the route are described in further detail below.

Bridge to Bridge

In the west, the route begins at the southern embankment of the existing State Highway 3 (Napier Road) Manawatū River Bridge and follows the alignment of the existing State Highway 3 route for a short distance, before connecting with State Highway 57 (Fitzherbert East Road) with a roundabout.

From the roundabout, the route curves to the east and north toward the Manawatū River. The roundabout will also provide for vehicle access to the carpark and rest facilities at the end of the Department of Conservation walking tracks in the Manawatū Gorge. An underpass or access beneath the new bridge over the Manawatū River will be required for property access.

New Manawatū River Bridge

A new bridge will cross the Manawatū River and Palmerston North to Napier Railway line at the mouth of the Manawatū Gorge. The bridge provides two lanes in each direction and will accommodate cyclists on the road shoulder, but not pedestrians. The final width will depend on the outcome of safety audits and the final design. The bridge will be approximately 30 metres above the current normal river level.

The design for the new bridge is yet to be confirmed. Specific design considerations for this bridge are discussed in the following sections.

Western Slope

North of the new bridge crossing, the alignment climbs to the north (and to the west of the Manawatū Gorge Scenic Reserve) before curving to the east through an area of cut and crossing a gully and unnamed stream (QEII covenant area).

Te Āpiti Wind Farm and Ridge

The route traverses the Ruahine Ranges eastward through the Te Āpiti wind farm. The route will pass through areas of cut and fill in order to maintain an appropriate vertical geometry and to achieve greater balance of the earthworks volumes.

The current Project design requires the removal of at least one wind turbine in the Te Āpiti wind farm along with the realignment or rationalisation of some turbine access tracks and associated electricity and fibre optic cables. Vehicle access within the wind farm site, and across the new State highway, will be via an underpass.

The design of the Project in this section will be developed in discussion with Meridian as part of the final detailed design.

A property containing an existing, closed, landfill is located towards the east of the ridge top. Any disturbance of the known area of the landfill will need to be limited and carefully managed in accordance with contaminated land standards.

Eastern Slope

From the ridge top, the route descends to the south east through farmland towards Woodville. An unnamed stream at the foot of the Ruahine Ranges, and to the west of Hope Road, is traversed by a bridge structure. Farm access is also required at this location and may be provided by an underpass (culvert structure), or in conjunction with the stream crossing bridge.

Woodville Gateway

The route reconnects with the existing State Highway 3 (Napier Road/Vogel Street), Troup Road and Woodland Road via a roundabout.

1.5.2 Geometric Design

An indicative geometric layout for the Project has been developed to confirm the appropriate extent and location of the designation to accommodate the Project works, including environmental management measures and construction activities. This alignment is also used as the basis to identify the potential effects on the environment along with potential mitigation measures.

The typical road cross section, along the route consists of:

- A two lane single carriageway highway with crawler lanes provided due to steep grades. Due to the grades, the crawler lanes extend for a majority of the length of the route
  - 3.5 metre wide traffic lanes;
  - 1.5 to 2.0 metre wide outside shoulders;
  - a central median which will be typically between 4.0 and 6.0 metres wide;
- A central median and wire rope barriers along the full route. TL5 HT rail barriers will typically provide edge protection on the bridge structures.
- Design speed of 110 km/h.

The route will provide for over dimensional vehicles of up to 10.0 metres wide and 6.0 metres high.

1.5.3 Indicative Bridges / Structures and Retaining Walls

The indicative main alignment and geometric design provides for up to seven potential bridge structures, as outlined in Table 1. However, as the NZ Transport Agency is currently seeking to enable works within a designation, the detailed design of the Project may feature more or fewer bridges. Further, locations for large drainage culvert structures have not been established in any detail, at this stage of the project, but are expected to be more fully identified as part of detailed design development of the final alignment.

The general location of the potential bridges featured in the current indicative design is shown in Figure 1.

The bridges outlined in Table 1 have been identified in order to satisfy Project geometric design and property access requirements. The proposed bridge at ~CH5665 has been identified as a means of minimising impacts to the QEII covenant area. Options for a separate bridge north of the river (~CH4060) will be dependent on development of the main alignment in the final design.

Indicative spans and overall bridge length noted in Table 1 are likely to change as part of final design development. It is possible that other bridge or culvert structures will be required as the detailed design of the Project is progressed.

In addition to bridges, retaining walls (generally mechanically stabilised earth (MSE)) or reinforced soil embankments (RSE) are anticipated to be required along the route. Locations for any retaining walls have not been established in any detail, at this stage of the project but are expected to be more fully identified as part of detailed design development of the final alignment.

Table 1: Indicative potential bridge structures

Bridge	Approx Chainage (m)	Function / Obstacle Crossed	Number of spans [1]	Length [1]
01	3235	Underpass for local property access	1	~6m
02	3600	Manawatū River	3 to 4 spans[2]	330 to 400m[2]
03	4060	Wetland area north of Manawatū River	2 to 4[2]	~150m[2]
04	5665	Route over gully and stream in QEII covenant area	1	~30m
05	8340	Underpass for Meridian wind farm access	1	~6m
06	10300	Underpass for local property access	1	~6m
07	12970	Route over stream	3[2]	~80m[2]

(1) To be confirmed during detailed design.
(2) Dependent on bridge configuration, to be determined through detailed design.

Figure 1: Indicative main alignment and potential bridge locations

2 GUIDING PRINCIPLES

2.1 Influences on Design

Options for bridge and retaining walls solutions have generally been developed with regard to a number of key factors including:

- Design standards
- Environmental considerations
- Cost competitiveness with consideration for whole of life costing
- Aesthetics
- Seismicity/Flooding
- Geotechnical conditions
- Durability and maintenance

The detailed design of the Project structures will be carried out with regard to these key factors. The key factors are outlined in more detail below.

2.1.1 Design Standards

Design standards outline the technical requirements for the design of bridge structures, including loadings (traffic, wind, seismic etc) and material design and detailing requirements (concrete, steel etc).

Designs are to be developed in conformance with the NZTA Bridge Manual (NZTABM) Third Edition, which sets out the criteria for the design and evaluation of bridge structures as well as the design of earthworks and retaining structures. Other relevant technical design standards include:

- NZS 1170 Part 5 – Seismic Loading Standard
- NZS 3101 - Concrete Structures Standard
- NZS 3404 – Steel Structures Standard
- AS 5100 – Bridge Design Code (Australia)

Design loading from the NZTABM is considered to cater for the effects of high productivity motor vehicles (HPMV) on the designs without any further modification.

The roadway geometric design will determine bridge widths. Bridges carrying the main alignment will accommodate the required number of traffic lanes, in addition to shoulders, verges and central reserves, as required by the Project geometric design.

Underpasses, to provide access under the Main Alignment to private property and areas of the Te Āpiti Windfarm severed by the Main Alignment will be required. Underpasses will be sized to accommodate normal road vehicles or special equipment identified by property owners (e.g large cranes used on the Te Āpiti wind farm).

Clearances under the bridges will follow the recommendations of Appendix A of the NZTABM.

2.1.2 Environmental Considerations

2.1.2.1 General

There are a number of sensitive ecological systems within the designation corridor. These will need to be taken into account in development of the Project design solutions, including consideration of alignment options, culvert, embankment and bridge structure solutions. The effects of permanent works and any temporary works/construction requirements will also need to be taken into account as part of selection of the final design, in order to minimise the impact of the Project on these ecologically sensitive areas.

2.1.2.2 Manawatu River Crossing

Design of this bridge will be required to take into consideration a number of environmental factors. These include, but are not limited to, the surrounding environment, effects of piers in the river bed, cultural significance of the area, the current use of the area (i.e. car park) and walking track access.

All options will seek to avoid physical encroachment into the existing legal property boundary of Parahaki Island (to the north of the bridge alignment) and the Manawatū Gorge Scenic Reserve (to the south of the bridge alignment).

Consideration of long span bridge solutions for the Manawatū River Bridge aims to minimise the impact of piers in the waterway on flooding, scour and gravel movement, particularly in and around Parahaki Island. Construction effects, in terms of temporary works to access pile locations within the river bed, will be reduced with fewer piers within the waterway.

2.1.2.3 Other bridges

In some instances, bridge options have been included where culverts would have provided a satisfactory and more economic engineering solution. A bridge over a branch of the western QEII covenant (~CH5665) is proposed, as encroachment of the embankment fill slopes within the gully would be substantial with a culvert solution, due to the steep and deeply incised terrain. Bridge solutions may also offer potentially better environmental solutions compared to culverts, such as maintaining existing stream bed environments and stream habitats.

2.1.3 Cost Considerations

Best value bridge solutions, with due consideration for whole of life performance, are recommended ahead of cheapest conforming design options.

Reinforced concrete and/or prestressed concrete bridges are proposed for all bridges with shorter spans (spans up to approximately 35m). Steel composite bridge structure solutions are proposed as options for the longer bridge span arrangements.

The use of substantially heavier post-tensioned concrete box superstructures are not precluded, although these forms of structures require significantly heavier substructures, particularly in areas of high seismicity.

The proposed Manawatū River Bridge is the most significant structure on this Project. Depending on pier arrangements adopted in and around the river bed, spans in the order of up to 90m may be required, with piers within the waterway. Span lengths up to 180m may be required for this bridge, if solutions are adopted avoiding piers within the waterway.

As indicated above, there are a range of superstructure and substructure solutions for this bridge structure, each with differing arrangements, construction and permanent footprint effects. These are expected to be considered in detail as part of developing the final bridge structure option at this location.

Two potential steel structure options are presented in Section 3.5, including a brief summary of the advantages and disadvantages of each approach.

2.1.4 Aesthetics

2.1.4.1 General

Appropriate aesthetics are important in roading schemes and consideration has been given to this in the development of the structural concepts presented as possible options for the bridges on the Project. It is noted that the route is generally a rural highway with few vantage points for road users to view structures, except for the bridge crossing the Manawatū River.

Bridge aesthetics should be considered in conjunction with the principles in the Project ECDF and NZ Transport Agency guidance (e.g. Bridging the gap).

With regard to the bridge over the Manawatū River, selection of the overall bridge form and proportioning of major structural elements that make up the bridge should be given high consideration in the development of the bridge solution at this location.

The bridge has the potential to be a dominant built structure in a rural landscape. Given its sensitive location on Manawatu Gorge, any design for this bridge should consider the surrounding environment and landscape, sites of cultural significance (e.g. Parahaki Island), effects of any piers in the river bed and current land uses.

For other bridge structures on the Project, the bridges shall achieve a logical and well defined overall composition, compatible with their location.

2.1.4.2 Retaining Walls

Locations for any retaining walls have not been established in any detail, at this stage of the Project, and will be more fully identified as part of detailed design development of the final alignment.

It is expected that retaining walls or reinforced soil slopes could be used to reduce the extent of fill embankments along the Project alignment. The selection of retaining wall or reinforced slope solutions is likely to consider a number of the broad guiding principles set out in this document, in terms of environmental and aesthetic impacts and cost considerations as well as engineering design aspects.

At bridge locations, consideration should be given to providing a spill thru abutment configuration, in keeping with the rural environment which the route passes through.

Where possible, retaining wall/slope types that blend in with the rural environment should be favoured over wall options using concrete facings. This should be considered in the context of the Project ECDF.

2.1.5 Key Design Parameters

The Project will reinstate one of the key roading links within the Manawatū Region and further afield. Increasing the resilience, safety and efficiency of this connection are key project objectives.

Key risks to the Project include a high level of seismicity and the potential for flooding and scour in the Manawatū River at the mouth of the Gorge where the new route crosses the river.

2.1.5.1 Seismicity

The Manawatū Gorge is located in a region of high seismicity in the central North Island. Located immediately to the east of the Project area are the upper end of the Wellington Fault and the Mohaka Fault, along with a number of other active earthquake faults in the region (refer Figure 2). There is an

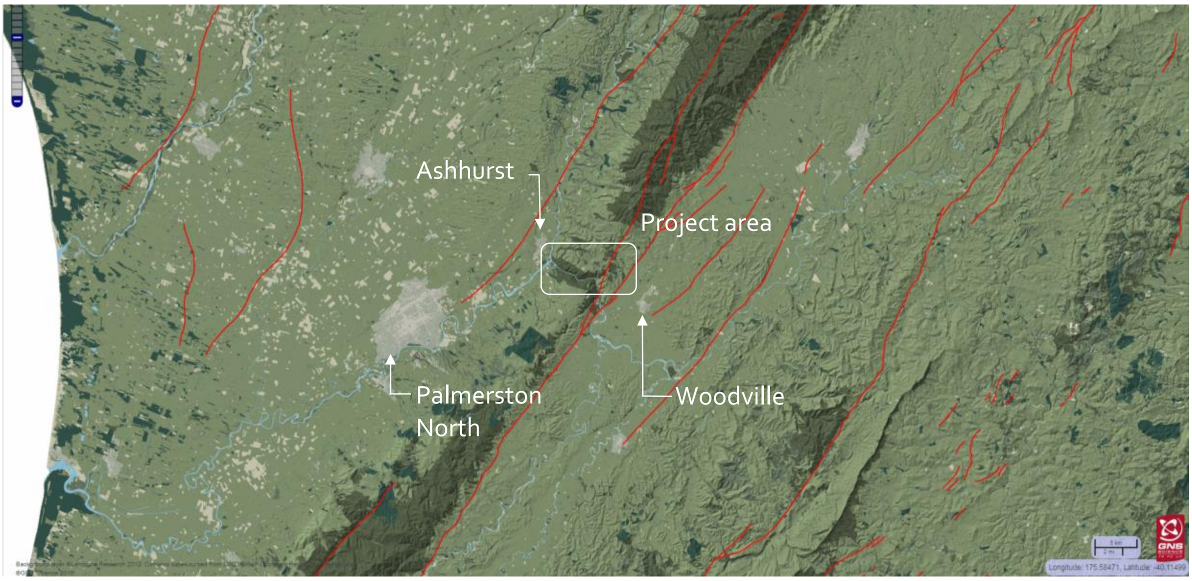


Figure 2: Active Faults near the Manawatū Gorge (from GNS Active Fault Database)

inferred inactive fault line located at the eastern entrance to the Manawatū Gorge, near the Manawatū River Bridge site.

Given the route's significance in terms of roading network resilience and the close proximity to active faults, it is suggested that a site specific seismic hazard study be completed in accordance with the requirements of the NZTABM, to estimate the seismic design spectra for determining seismic loadings for bridges, retaining walls and embankments on the Project. This site specific study should consider the potential for and possible contribution from any inferred inactive faults in the vicinity of the Project and their contribution to seismic hazard risk.

Robust structural forms with high levels of redundancy should be adopted for the bridges wherever possible. Integral structures are suggested to provide robustness and redundancy under seismic loads.

'Low damage' seismic design approaches (use of base isolation and possibly rocking foundations) are desirable for the larger bridge structures, in particular, given the high seismicity of the region. This is to ensure reduced potential for structural damage and reduced disruption following a large earthquake.

Mechanically stabilised earth (MSE) walls are suggested for vertical retaining walls and reinforced soil embankments (RSE) for embankments detailed with 45° (or steeper) slopes. Both solutions are expected to give good performance in earthquakes.

2.1.5.2 Flooding

Another risk to route security is flooding predominantly within the Manawatū River.

Specific detailed hydraulic studies will be required as part of the detailed design stage to confirm the proposed design and location of pier positions for this bridge are appropriate and do not create any adverse effects on the existing river banks and to Parahaki Island immediately downstream of the bridge site.

2.1.6 Geotechnical Conditions

Preliminary geotechnical investigations have been undertaken to support preliminary design of the current route. Investigations were scoped to provide basic initial data that could be used to aid in the broad characterisation of the engineering geological and geotechnical ground conditions and constraints along the route. Fifteen (15) cored machine boreholes were completed, in addition to engineering geological mapping, along the length of the route.

Generally, siltstone or sandstone was encountered in each borehole, overlain by a mix of silt/gravel layers of varying thickness along the route.

Pending further detailed geotechnical investigations and interpretation, ground conditions are expected to generally suit bored piled foundations socketed into the siltstone/sandstone or embedded into dense gravels for the bridge structures. Shallow spread foundations may be appropriate for the shorter span, smaller box culverts and underpasses.

2.1.7 Durability & Maintenance

Durability and maintenance requirements specified in the NZTABM and relevant materials design standards should be readily achieved. Given the location of the Project, remote from the coast, use of weathering steel for the larger span steel structure(s) is considered to be feasible. This would address aspects with the need for the ongoing maintenance and replacement of coating systems associated with traditional mild steel construction.

Where ever possible, integral abutments and piers should be considered for the bridges, to eliminate maintenance associated with bearings and joints.

With longer span bridges, where joints and bearings cannot be avoided, adequate provision for inspection and maintenance of bearings and joints should be provided.

3 BRIDGE FORMS

3.1 General

Proposed bridge forms listed below are considered to offer appropriate bridge structural solutions which meet the guiding principles outlined above. Different design solutions are proposed for different bridge span arrangements. The solutions proposed are feasible to meet design standards and offer cost competitive, robust and durable structures.

The following deck forms are considered as potential bridge structure solutions for the Project:

- Spans up to 6m – Reinforced concrete box structures.
- Spans up to 25m – Generally hollow core prestressed concrete decks.
- Spans ranging from 25m to 35m – Super 'T' prestressed concrete girder decks.
- Spans ranging from 35m to 60m – Steel 'I' girders or steel box girders with composite reinforced concrete deck slabs. Concrete box girders are also feasible.
- Spans > 60m (Manawatū River Bridge) – Steel box girder beam arrangement (continuous span arrangements up to 60m) or balanced cantilever construction, steel truss, steel box girder or concrete box girder (continuous span arrangements >60m).

Attributes of the different bridge structure types considered are outlined below. Options presented are considered to be feasible and appropriate for this Project. Final built form of the structures will be determined in the detailed design phase of the Project. Other equally suitable alternatives, not outlined herein, may form part of the final solution.

Illustrations and photographs of various deck arrangements suggested for this Project are found in Figure 3 below.

3.2 Reinforced Concrete Box Underpasses

Short span underpasses are economic, robust, fully framed reinforced concrete box type structures to provide vehicle passage for property access.

These structures can also be adopted for use as large culverts, with consideration given to provision of fish passage requirements through these structures (e.g. setting base below natural stream bed level, design of appropriate internal baffles etc, to create a suitable fish passage environment). Alternative culvert forms, such as arch culverts, are also feasible, and would offer options for retaining the existing natural stream bed. Culvert form and design should be considered taking into account the advice of the Project freshwater ecologist during the resource consent application stage of the Project.

3.3 Standard Precast Concrete Beam Superstructures

3.3.1 Hollow Core Superstructures

Hollow core prestressed concrete deck superstructures are a proven solution with excellent robustness and economy for spans up to a maximum of 25m. These types of deck can easily be detailed as fully integral with piers and abutments.

3.3.2 Super 'T' Superstructures

For spans between 25m and 35m Super 'T' prestressed concrete girders with cast in situ top slab provide excellent economy and long term performance. These types of deck can easily be detailed as fully integral with piers and abutments.

3.4 Steel or Concrete Superstructures, 35m – 60m

3.4.1 Steel "I" Girders or Steel Box Girders with Composite Reinforced Concrete Deck

Seismic demand on foundations is a function of a structure's height as well as its structural mass. Steel composite bridges are much lighter than concrete equivalents and would be a viable solution for taller, longer span bridges (say pier heights in excess of 12m and spans between 35m to 60m).

In the case of the taller bridges, more economic and efficient substructure solutions are possible due to reduced seismic demand compared with the much heavier concrete only alternatives.

3.4.2 Concrete Box Girders

Concrete box girders are significantly heavier than a steel composite equivalent superstructure. Substructures would be significantly larger due to increased weight and seismic demand compared with the lighter, steel alternatives. This superstructure form remains appropriate for the span range and therefore should not be precluded as a potential option.

Precast, prestressed (and/or post-tensioned) concrete beams are not commonly available for spans significantly greater than approximately 39m. Beam elements of this span range will also be relatively heavy to lift into position.

3.5 Steel or Concrete Superstructures, >60m (Manawatū River Bridge)

The Manawatū River Bridge is the only bridge of the size and scale on this Project where bridge spans exceeding 60m are likely. There are a range of superstructure and substructure solutions for this bridge structure, each with differing arrangements, construction and permanent footprint effects. Two options are presented below, considering different pier arrangements to be adopted in and around the river bed, for this bridge.

The final built form of this bridge will be determined in the detailed design phase of the Project. Other equally suitable alternatives, not outlined herein, may form part of the final design solution.

3.5.1 Option A: No piers in the river option

Based on the indicative main alignment, the main span of this arrangement would be in the order of 180m long with a minimum back-span length of around 110m anticipated (60% of main span, for efficient balanced cantilever design).

A balanced cantilever type arrangement using haunched steel or concrete box girders or a variable depth steel truss superstructure arrangement would be most feasible for this bridge option. A visualisation of this potential bridge option can be found in the Structures Drawings in Volume 4.

Construction of the main span over the river using a cantilever or balanced cantilever approach is considered to be feasible.

3.5.2 Option B: Limited number of piers in the river

A pier (or piers) in the river reduces the bridge spans to 90m or less. This would make this bridge structure more suited to a constant depth steel box girder or steel 'I' girder superstructure arrangement, depending on number of piers and span lengths. A visualisation of this bridge option can be found in the Structures Drawings in Volume 4.

A concrete box girder superstructure would be feasible, but will have increased weight and substructure sizes compared to a steel option.

Depending on road alignment geometrics, construction of the steel bridge by launching the superstructure from the abutments may be feasible. This would minimise construction requirements for cranes and lifting of superstructure components, particularly out over the river.

3.5.3 Other forms of bridge structure

Other forms of construction such as cable stay, arch or suspension bridges are not considered to be best suited to roading geometries that are curved in plan. Based on this and the other guiding principles presented here, they are not considered to feature as likely bridge structure options in the final design (although are not precluded from consideration).

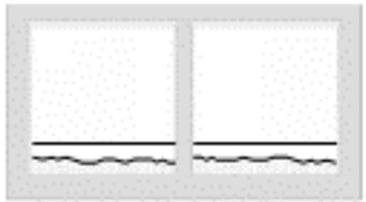
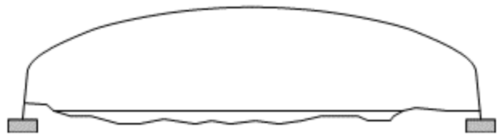
Type	Notes	Detail	Illustration
Box Culverts	The larger box culverts through the route should be sized to enable easy debris clearing by machine and, as a result, generally should have considerable reserves of hydraulic capacity. The structures would likely be constructed from either in-situ or precast concrete, or a combination of both. Provision for fish passage can be made through allowing for natural stream bed materials in the base of the culvert or design of specific elements in the base of the culvert to create a suitable passage.	 Twin Cell Box Culvert	
Corrugated Pipe or Arch Culverts	Corrugated pipe or arch culverts can be provided, in lieu of concrete pipe or box culverts. These allow for re-creation of a more natural stream bed environment to maintain fish passage. In the case of arch culverts, the existing natural stream bed could be retained, and not disturbed.	 Corrugated Arch Culvert	

Figure 3: Bridge Types for the Project

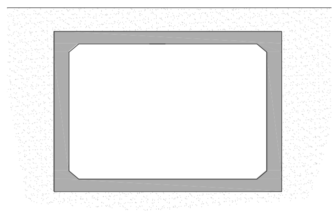
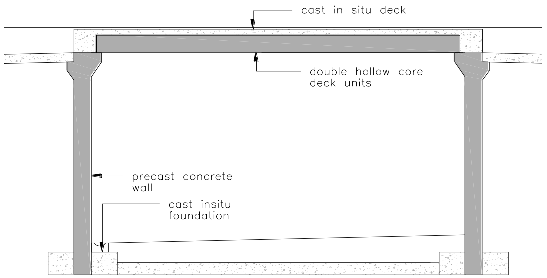
Type	Notes	Detail	Illustration
Underpass Structures (Typical clear spans ranging from 6m to 10.6m.)	Underpasses are required for property or vehicle access in a number of locations along the route. Shorter span underpasses can be detailed as robust cast in-situ boxes. These underpasses could also be assembled from precast or part precast/ part in-situ elements. Longer span underpasses are typically detailed with precast concrete walls with reinforced concrete foundations supporting hollow core deck units. The fully framed structural form would provide a durable and robust solution for the larger underpasses. Another viable option for the longer span underpasses include hollow core units supported on reinforced soil walls (see photograph opposite).	 Reinforced concrete underpass  Underpass with Hollow Core Deck on Precast Concrete Walls	 Underpass with Hollow Core Deck supported on MSE walls

Figure 3 (cont): Bridge Types for the Project

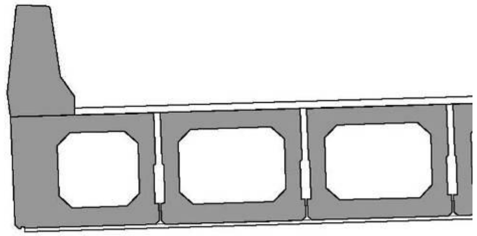
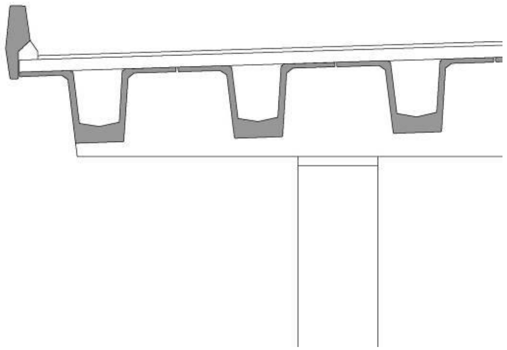
Type	Notes	Detail	Illustration
Spans Up To 25m: Prestressed concrete Hollowcore bridges	This economic, robust, durable and frequently used bridge solution is proposed where spans up to 25m are required. Deck units are typically supported on reinforced concrete cap beams founded on cast in-situ bored piles. Hollow core deck units supported on reinforced soil walls may also be a viable option.	 Hollow Core Bridge Deck	
Spans Between 25m & 35m: Prestressed concrete Super T bridges	Economic, robust, durable and frequently used bridge solutions where spans between 25m and 35m are required. Widely available from most contractors/precast manufacturers. The precast beam flanges provide a safe working platform during construction of the insitu deck slab.	 Super T Bridge Deck	

Figure 3 (cont): Bridge Types for the Project

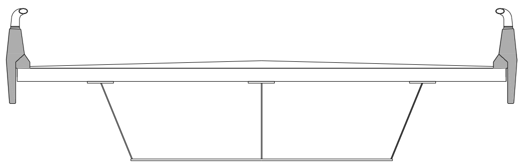
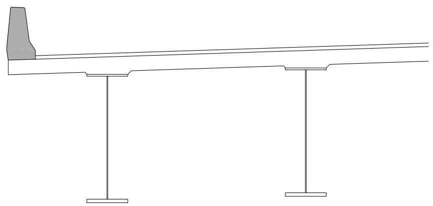
Type	Notes	Detail	Illustration
Spans from 35m to 60m: Steel Composite Bridges	Steel bridges provide cost effective solutions for longer-span, taller structures, and may be suited for crossings, particularly where steep topography and difficult access may favour fewer piers and longer spans. Steel composite structures weigh significantly less than their concrete equivalents, making construction easier in difficult country with significant savings in substructure costs. Modern coating systems, such as metal zinc spray and single coat inorganic zinc silicate systems, provide highly-durable protection for extended periods (up to 40 year's time to first maintenance).	 Steel box girder bridge  Steel 'I' girder bridge	 Steel box girder bridge  Steel 'I' girder bridge

Figure 3 (cont): Bridge Types for the Project

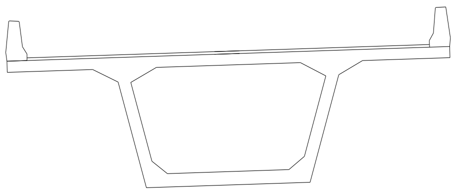
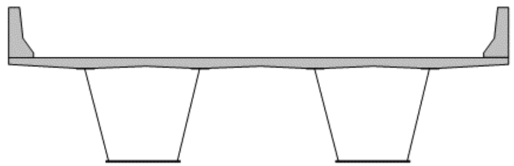
Type	Notes	Detail	Illustration
Spans more than 60m: Post-tensioned concrete Box Girder Structures	This form of bridge would suit the crossing of the Manawatū River which may have spans of 90m to 180m. A haunched concrete box configuration is likely to be most structurally efficient for a concrete box girder of this span length.	 Post tensioned concrete box girder bridge	
Spans more than 60m: Steel Box Girder Structures	This form of bridge would suit the crossing of the Manawatū River which may have spans of 90m to 180m, and would be significantly lighter compared to a concrete equivalent. A constant depth superstructure may be feasible for span lengths at the lower end of the range. A haunched box configuration is likely to be most structurally efficient for longer span lengths. Steel box girders would be composite with a reinforced concrete deck slab.	 Steel box girder bridges	

Figure 3 (cont): Bridge Types for the Project

Holmes

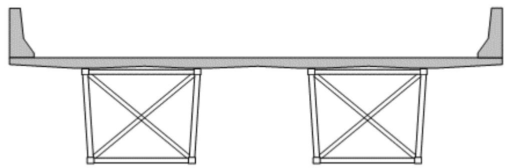
Type	Notes	Detail	Illustration
Spans more than 60m: Steel Truss Bridge	This form of bridge would suit the crossing of the Manawatū River which may have spans of 90m to 180m. A haunched steel truss deck configuration may be configured to allow for a cantilever (or balanced cantilever) construction methodology for the main span across the river.	 Haunched steel truss bridge	

Figure 3 (cont): Bridge Types for the Project

4 RETAINING WALLS

4.1 General

Retaining walls will serve a number of purposes, including forming bridge abutment walls and supporting bridge approaches, as well as supporting embankments and cut slopes.

Locations for any retaining walls have not been established in any detail, at this stage of the Project and will be more fully identified as part of detailed design development of the final alignment.

Walls will be designed to meet the requirements of the NZTABM.

4.2 Types of Walls

The two main types of retaining structure that have been considered for this Project are noted below. Other retaining wall types are available and may be adopted, depending on development through the detailed design phase of the Project.

- Mechanically stabilised earth (MSE) walls for vertical walls.
- Reinforced soil embankments for embankments with slopes equal to or greater than 45°.

Benefits and disadvantages of the above wall types are described in Figure 4. Details of the wall solutions are noted in Figure 5 below.

4.3 Earthquake Performance

Only robust wall types with proven good performance in earthquakes will be used for this Project.

Both MSE walls and reinforced soil embankments can be designed to undergo earthquake displacement and can be expected to perform well. Roads supported by these walls should remain serviceable after a major earthquake, although some surface cracking may occur, and repairs to facing panels may be required.

4.4 Retaining Walls Supporting Highway on Slopes/Embankments

In some locations, lengths of road may be supported by a retaining wall/reinforced slope with a steep natural slope below. Retaining walls in these locations may serve to reduce the footprint of the fill embankment encroaching on the slope or gully below. They may also benefit in allowing a reduction in culvert length beneath the carriageway formation.

A MSE wall may be appropriate in these locations provided suitable founding can be achieved for the wall.

A more cost-effective alternate solution could be to replace sections of a retaining wall with a 45° (or steeper) sloping reinforced soil embankment. This solution can be used where there is sufficient space available to accommodate the additional width of the inclined reinforced slope.

Retaining Wall Type	Advantages	Disadvantages	Application for route
MSE Walls	Suitable for supporting fill with a vertical or semi-vertical face. Can accommodate a displacement-based design approach for high seismicity. Allow construction using suitable on-site materials, and can be built in conjunction with earthworks operations. Able to accommodate some settlement on compressible ground.	Require space to form reinforced soil block. Concrete panel or block facing may not be best suited to rural environment – to be considered in conjunction with Project ECDF.	Suitable for bridge abutments or approaches. Suitable for walls supporting highways on steep slopes, assuming they can be founded on stable level ground.
Reinforced Soil Slopes	Suitable for supporting fill with a semi-vertical face. Can accommodate a displacement-based design approach for high seismicity. Allow construction using suitable on-site materials, and can be built in conjunction with earthworks operations. Able to accommodate some settlement on compressible ground. Face of wall can be planted to blend in with local environment.	Require space to form reinforced soil block.	Suitable for walls supporting highways on steep slopes, assuming they can be founded on stable level ground.

Figure 4: Retaining Wall Types & Applicability

Type	Notes	Detail
Mechanically Stabilized Earth (MSE) Retaining Walls	These types of structures are one of the most widely used in New Zealand and overseas, and rely on metal straps or geotextile grid reinforcement embedded in the fill behind face panels to provide embankment stability. Walls are typically faced with concrete panels or modular concrete blocks. Retaining walls may be required to support bridge abutments, approaches and retention of embankment fill slopes at the entry and exit of access underpasses under the route. Inextensible reinforcement is required for walls supporting bridge abutments (e.g. steel strips), with selected granular fill within the reinforced earth block. Modular block facing with geogrid reinforcement may be appropriate for retaining walls not supporting bridge abutments.	
Reinforced Soil Embankments (RSE)	Steeper embankments are achievable by introducing layers of geogrid between embankment fill layers. A more natural appearance can be achieved, where space permits, by incorporating suitable growing media in order to support vegetation on the wall face. Sloped or near vertical slopes can replace vertical (concrete) retaining walls.	

Figure 5: Retaining Wall Types Proposed for the Project